BattleChip

Requirements and Functional Specifications

EE 483 - Senior Design

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Revision History

Version	Author	Date	Reason for Change
0.1	Team	9/14/2018	N/A
0.9	Team	9/21/2018	First Draft Released
0.95	Erik Torkelson	9/28/2018	General Edits
1.0	Kristin Taylor	10/12/18	Final Revisions

Table 1- Revision History

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INTRODUCTION

The BattleChip project is a prototype for a modern digital version of the well-loved childhood game Battleship, which has been around since World War I. This updated version will include many improvements and unique features that allow for a more interactive experience. These include, an LED playing field for each user, with sounds effects and color coding, digitized control buttons, as well as an updated and compact case. The various improvements will allow the iconic board game to be more marketable to modern children and the present-day toy industry. Our team was motivated to transform this well-loved game because we all grew up playing it and by creating a fully digital version we are able to showcase what we have learned in our courses here at the University of Portland. By taking on this project our team hopes to gain critical design skills that are necessary to pursue a career in the digital design field, teamwork skills that will help us in the workforce, as well as become overall stronger leaders. The rest of this document will outline the requirements, processes, risks, milestones, and other information that describes specifically what our project is.

Figure 1 - The Original Battleship Board Game

Requirements

Overview

The BattleChip project contains a game logic controller, two Raspberry Pis, two display controllers and two LED matrices. The diagram below lays out the entire design by showing the interaction between all these devices, including the connections between the different components. Each net shown below is labeled descriptively with the appropriate direction of transmission, the signal or data being sent, and the number of bits each signal will be. By developing our project using a top down methodology it will allow each module to be developed separately and.

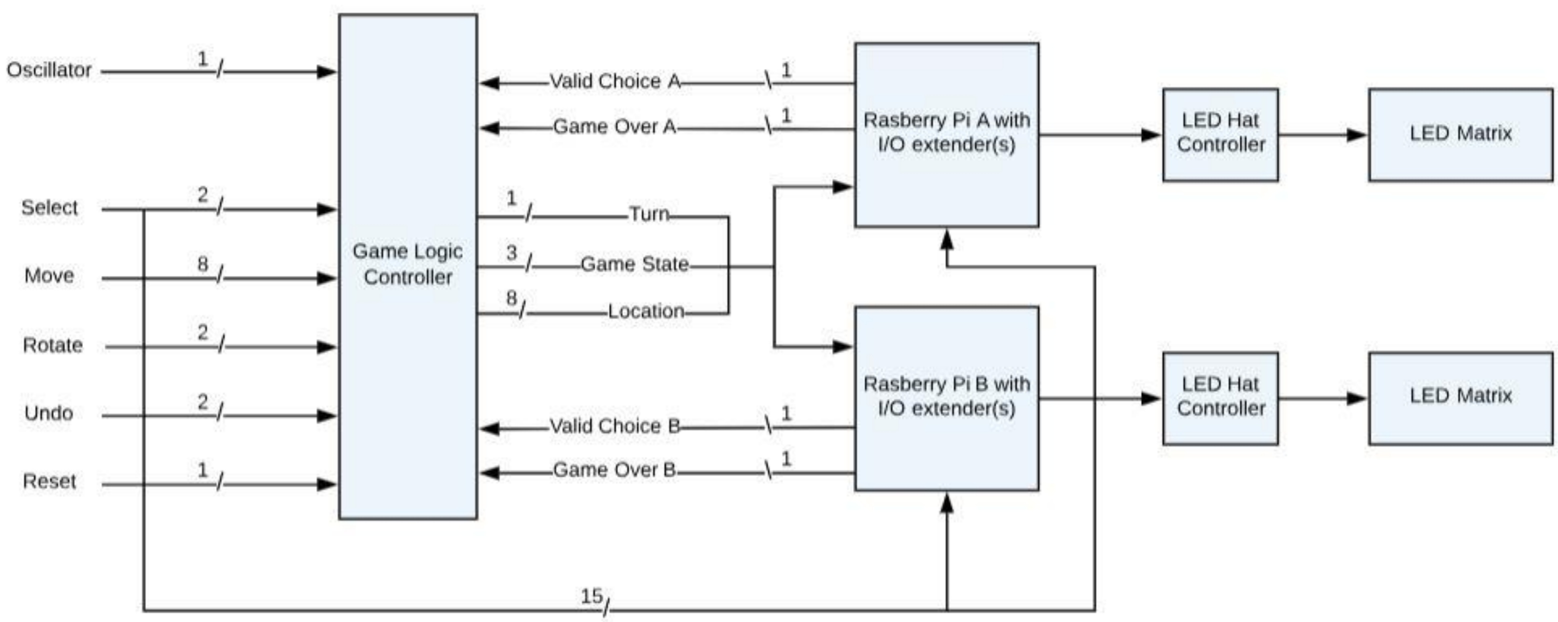

Figure 2 - Top-Level Block Diagram

The game logic controller is the primary computation device in the project, and it performs all the logical calculations required for most aspects of the game. It will keep track of board positions, the state of the game, and player turns, which will be provided as an output to the display system. The controller interacts directly with the user inputs, i.e. buttons, and communicates with both Raspberry Pis to display the game on the LED matrices. It is designed as a main FSM that controls other sub FSMs. Each sub FSM will control a complete game stage and activate the corresponding logic required. For example, one sub FSM controls the placement of the ships on the board by the players. This helps keep the design modular and organized. The downside to having such a modular design is that it will probably use more space and resources on the chip.

The Raspberry Pi display system is the link between the LED matrices and the game logic controller. It receives updates on game events to display and does some minor processing as well. Due to size constraints of the chip, the locations of each players' ships are stored on this system. Therefor during gameplay, each Raspberry Pi will calculate if a specified location on the board is a valid choice and respond to the game logic controller accordingly. A position would not be valid if it has already been attacked during gameplay or intersects with a ship while determining each player's layout in the set-up stage. Each Pi will also send a signal if all its player's ships have been destroyed and the game is completed. Each Pi will be connected to an LED Hat controller, which is a small microcontroller allowing for easy control of the LED matrices. The LED displays show each player the state of the game and act as both the upper and lower half of a traditional battleship board. We decided to save space by having one screen per player and making them dual-purpose. This means that by pressing the swap screen button the user can choose if they are viewing their ship placement screen, or the screen which shows where they have attacked their opponent. This part of the implementation is where the design differs from traditional battleship.

General Specifications

Size – The device must hold 2 LED matrices each with 1024 LEDs. In between these will be space for two Raspberry Pis, a printed circuit board with the game logic controller, and an FPGA for the testing phase and contingency plan. Buttons and appropriate user inputs must also fit on the device.

Shape – The device will be placed on a flat surface such as a table for user interaction. The two players will sit opposite from each other on either side of the device. An example of the shape can be found in Figure 3. Each side will be slightly angled up to allow for easier viewing and more stability so it won't be knocked over.

Weight – The weight is not extremely important as the game will be played on a surface and will not be handheld. It should be heavy enough that it won't be easily knocked over but not too difficult to move around.

Operating Conditions – The device must be operated within normal conditions. It will be susceptible to water damage due to submerging or water entering through spaces around buttons. It will work in temperatures ranging from 0 degrees to 110 degrees.

User Safety – The device will be safe to handle and therefore must be electrically neutral. This will prevent any electrical discharge to the users. The case will be made from an insulating material and all electrical components will be safely housed inside the case.

Technical Specifications

Power Supply – The project will be powered by a wall power supply capable of driving at least 13A at 5V. This is about what all the components of the project will draw in terms of power. Using batteries instead would increase the weight and size of the project since it will draw so much electricity.

Clock Signal – The game logic controller requires a clock signal to function since it contains sequential logic elements. This will be generated by a small integrated circuit that we will purchase. For more information about this circuit see Appendix B.

Required Hardware – Most of the data processing will be done on the game logic controller which will be fabricated by the MOSIS Educational Program. It will be connected to the Raspberry Pis and user inputs with wires or on a PCB.

PRIMARY USE

Entertainment

The original goal of this project was to recreate the board game Battleship as a fully digital version. Therefore, the main use of this device will be for entertainment purposes. We wanted to create a device that would appeal to children of the younger generations as they are growing up in an age of technology. We considered user experience in the design of the device so it will be housed in an easily portable case, and will also have easy to use controls that will allow the device to be playable by all ages.

Education Aid

Another way our project could be used is as an education aid for undergraduate digital design courses. We utilized skills such as Verilog and top down design methodology which would be good examples for other students. More specifically, the design process of this device can be used to demonstrate techniques such as programming LED RGB displays, designing and implementing complex FSMs in Verilog, memory interactions and interfacing, and much more. These are important skills for those who want to pursue a career in digital design to create the next line of CPU's or electronic medical devices which contain digital logic.

Youth Education

In addition to being used to teach digital design courses, this device can also be used to teach strategy and other cognitive skills to young children. We envision this game will be used mainly by children from ages five to twelve years old. This game can teach then the strategy used to win Battleship, which is a valuable learning opportunity and similar strategy, such as the process of elimination, can be used elsewhere in everyday life. Board games such as this can also improve children's skills in "letter recognition and reading, visual perception and color recognition, and eye-hand coordination and manual dexterity" ("The Benefits of Board Games"). Our RGB LED matrices add a unique element of color and visual recognition.

USER INTERFACE

The design for our user interface was heavily influenced by the current battleship games you can purchase on the market. Since ours is fully digital we have an ON/OFF button on the side of the case as well as a RESET button which allows you to send the game back to the initial game screen so users can reset at any point in the game. The display will be a 32x32 LED array, and each “pixel” of a ship will be represented by 4 LED’s arranged in a 2x2 block to make it easier for the users to view the ships. The front view shown below in Figure 4 will be duplicated on each side of the case, for 2 players. The users will start playing the game by pressing the select button, and the move D-pad to move ships for placement and attack coordinates. The rotate and undo buttons are used for placing ships in the initial stage, and lastly the swap button allows the user to swap their LED array image from their placed ships to a view of where they have attacked on the other players board. Refer to Figure 3 and Figure 4 below for a visual of what the Case will look like from both a front and side view.

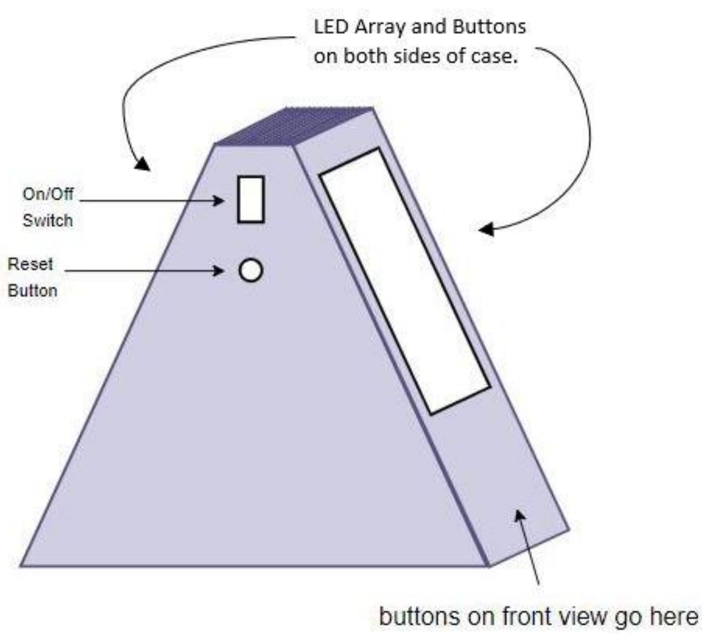

Figure 4 - User Interface Side View

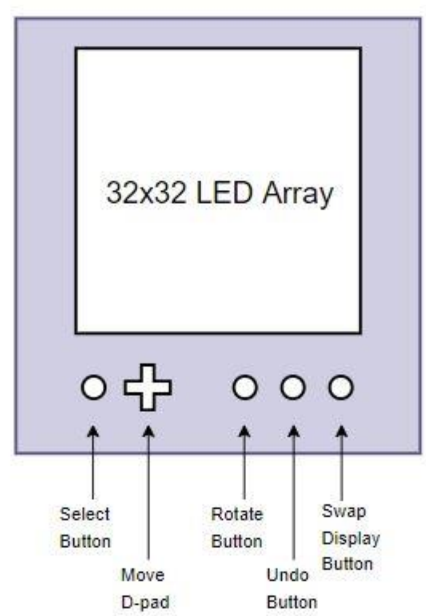

Figure 3 - User Interface Front View

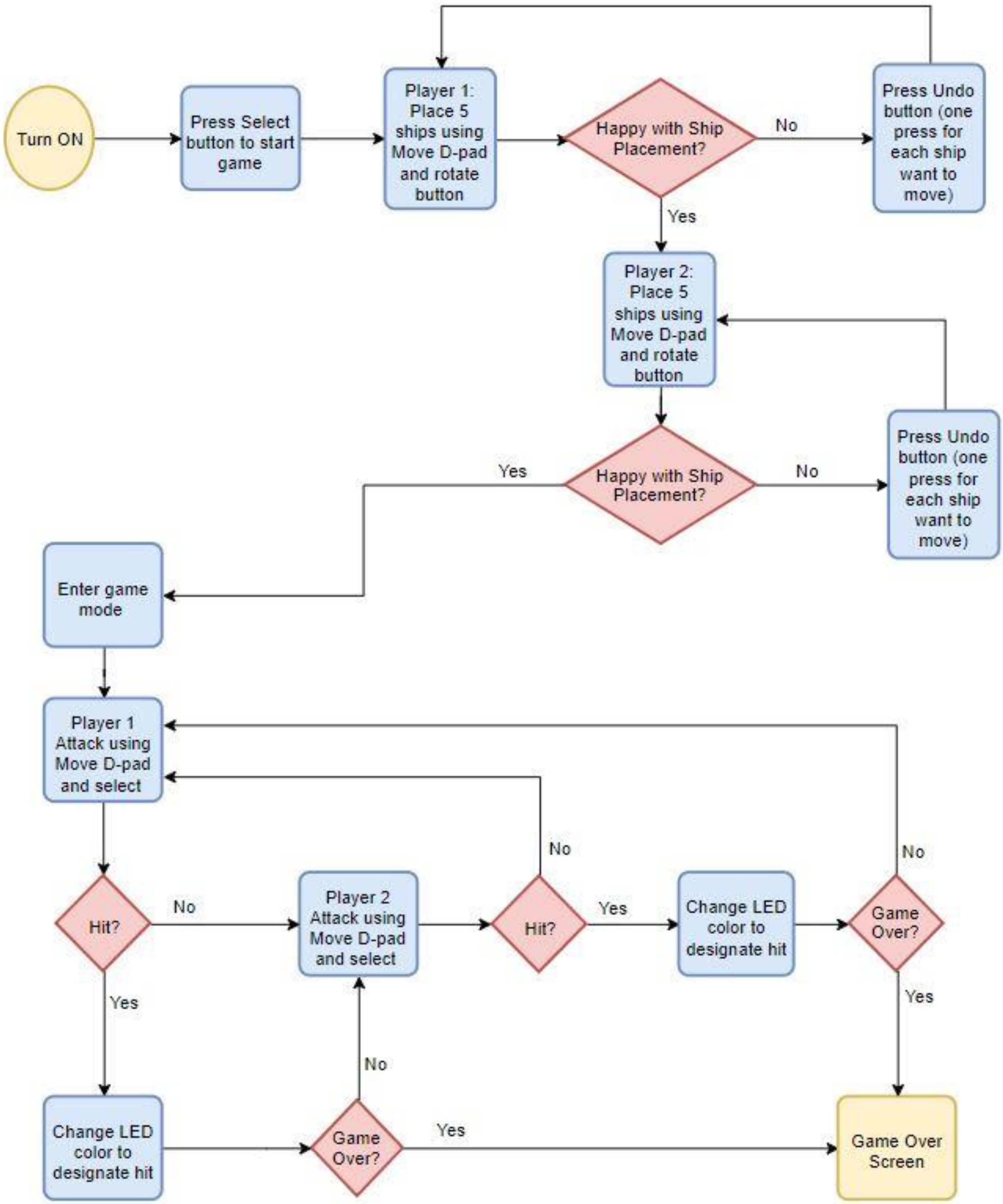

Figure 5 - Stages of Play

DEVELOPMENT PROCESS

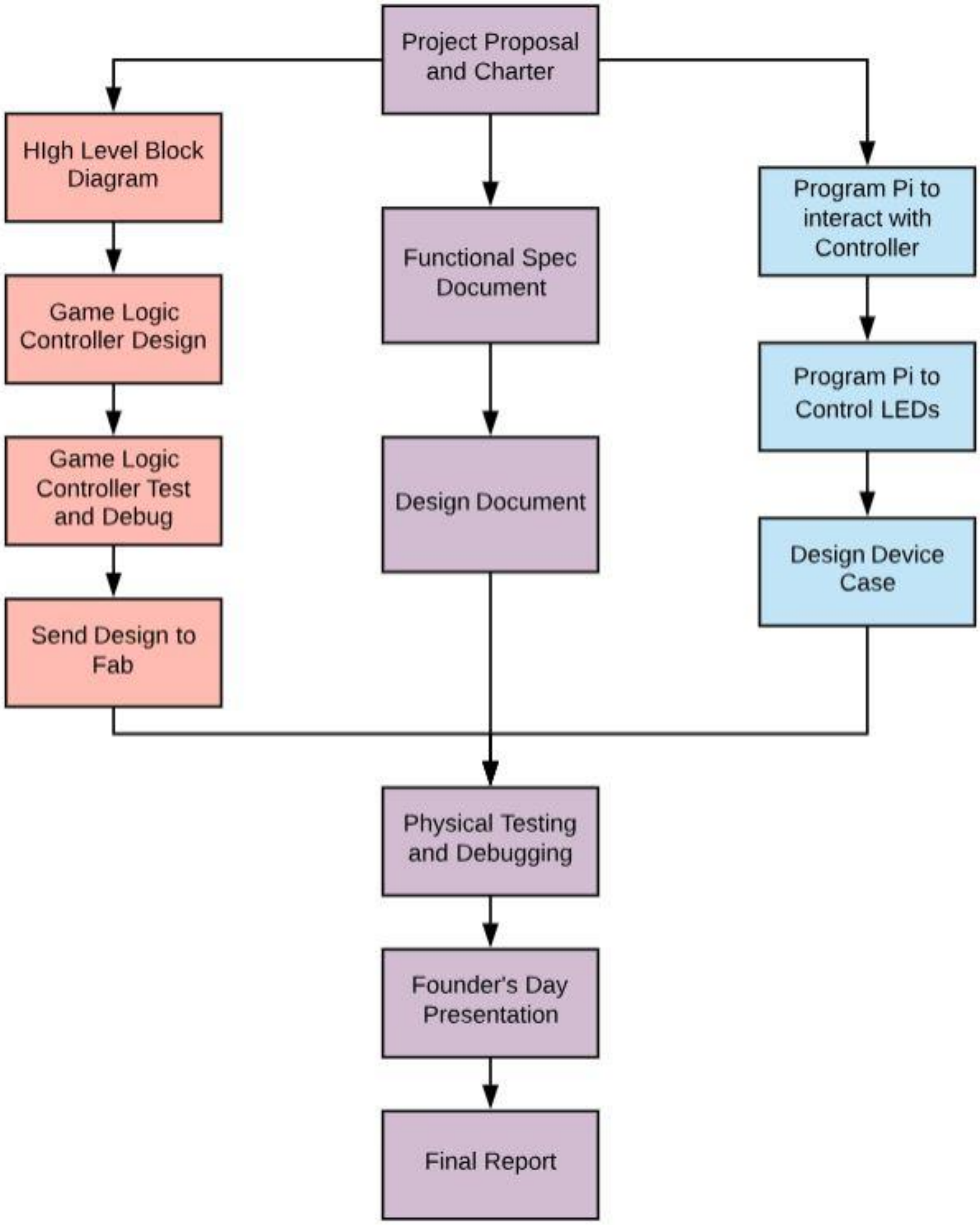

Figure 6 - Development Process

Project Proposal and Charter

The project was pitched by Erik Torkelson and Kristin Taylor to Dr. Osterberg. It was approved and Dr. Mansouri agreed to be the faculty advisor. Team roles were assigned depending on individual strengths and an appropriate charter was created to keep each member responsible.

Functional Spec Document

The team will write the Functional Specifications Document which fully describes the operation of the BattleChip Project. It includes how to use the project, high level block diagrams, milestones, constraints, and overall requirements. It will serve as a template during the design process.

High Level Block Diagram

Outlines the interaction between major components of the project such as the game logic controller, Raspberry Pi system, and LED matrices. Once this is determined, work can begin on different parts of the project in parallel.

Game Logic Controller Design

The game logic controller chip must be designed in Verilog and B2Spice for testing and fabrication respectively. The size constraints for the MOSIS chip must be kept in mind so that the entire design will not be too large. We also need to keep in mind the number of I/O pins available.

Game Logic Controller Test and Debug

The digital circuit that is designed must be simulated with Verilog with testbenches that mimic the interaction with the other components of the project. If simulation succeeds the design can be programmed to an FPGA for further physical testing. Once the design is verified to function correctly, the gate level circuit will be created in B2SPice.

Send Design to Fab

The final circuit will be exported to a netlist format which describes all the gates and interconnect. Standard place and route will be run on this to generate the layout schematic of the final chip design. This will be sent to MOSIS for fabrication.

Program Pi to Interact with Controller

Program the two Raspberry Pis in python to update their game boards based on user input and respond with the appropriate signals.

Program Pi to Control LEDs

The Raspberry Pis will be programmed to display the two different players' respective boards on the two different LED displays.

Design Document

The design document will present the specifics of the project design including digital logic schematics, FSMs and code functionality.

Design Device Case

The device case will be designed in SolidWorks and 3D printed at the university with the assistance of technicians.

Physical Testing and Debugging

With the arrival of the game logic controller chip, it will be tested for errors and verified to function correctly with our project. At this point in the design process, everything else should be finished so the FPGA can be easily replaced by the game logic controller.

Founder's Day Presentation

The final project will be presented during Founder's Day to students, faculty and advisors. There will also be a project demonstration.

Final Report

The final report document will encompass the entire project and what was accomplished. It will have all the details of the project.

MILESTONES

Milestones	Completion Date
Functional Specification Document (ver 0.9)	September 22, 2018
Functional Specification Document (ver 0.95)	September 28, 2018
Functional Specification Document (ver 1.0)	October 12, 2018
Final Budget	October 26, 2018
Initial MOSIS EDIF file completed	October 26th
Design Document (ver 0.9)	November 2, 2018
Design Document (ver 0.95)	November 9, 2018
MOSIS EDF file, Verilog schematic completed	November 16, 2018
Design Document (ver 1.0)	November 30, 2018
Website Updated with Fall Documents	December 13, 2018
Hardware Test	March 1, 2018
Prototype Built	March 22, 2019
Founder's Day Presentations	April 9, 2019
Website Updated with Spring Documents	April 12, 2019

Table 2 - Milestones

Functional Specification Document (Ver 0.9, 0.95, 1.0)

The Functional Specification Document fully explains the functionality, requirements, and scope of the project. Version 0.9 and 0.95 are the first drafts of this document which will be reviewed by our faculty advisor and industry advisor respectively. Version 1.0 is our final draft for submission.

Final Budget

The final budget is a detailed itemized list of every item needed to complete the project. Prices will be included for each item, as well as the number of units required.

Design Document (Ver 0.9, 0.95, 1.0)

The Design Document will contain all design-related feature of our project. These include low-level and high-level block diagrams, FSM drawings, and logic schematics and Verilog code. Versions 0.9 and 0.95 will be drafts of this document, while version 1.0 will be the final draft

Verilog Schematic

The Verilog Schematic is the logic gate level schematic extracted from our Verilog code. This will be recreated in B2Spice in order to be translated into an EDF file to be sent off for fabrication of the MOSIS chip.

Website Finalized with Fall Documents

At the end of the Fall semester our website will be update with completed and up to date version of all of the project documentation thus far.

Hardware Test

The functionality of our hardware must be tested to ensure it is working properly and as expected. This will ensure that each individual component is functional as well as when we put them all together.

Complete Prototype

Once the case is designed and all of the hardware is tested we must construct the final prototype. After it is wired and running each team member will take turns playing multiple games to test every functionality. The prototype of the LED Battleship will be presented and demonstrated on Founder's Day.

Founder's Day Presentation

The team will present our entire project for the student body, faculty, and industry advisors. This will include an explanation of our design process as well as a demonstration of our final product.

Website Finalized with Spring Documents

All finalized documents from our project will be uploaded to the team website. This will ensure all of our project documentation in in the same place for viewing.

BUDGET

Item	Quantity	Cost per Unit	Total Cost
Raspberry Pi Model 3B+	2	$40.00	$80.00
MicroSD Card	2	$10.00	$20.00
5V 2.5A Pi Power Supply	2	$10.00	$20.00
32x32 LED Matrix	2	$50.00	$100.00
LED Matrix HAT Controller	2	$25.00	$50.00
5V 4A Hat / LED Power Supply	2	$15.00	$30.00
Oscillator 555 IC	1	$10.00	$10.00
Chip Power Supply	1	$10.00	$10.00
Overall Power Supply / Brick	1	$30.00	$30.00
Shipping	1	$50.00	$50.00
TOTAL			$400.00

Table 3 - Budget

FACILITIES

The Shiley 306 lab will be used to assemble and store the device and its components. In addition, the game logic controller will be manufactured at the MOSIS factory in Marina del Rey, California. The device casing will be built by a 3D printer located in one of the Shiley Labs on the first floor.

TECHNICIAN ASSISTANCE

Jared Rees will assist the team in developing a PCB to cleanly route wires and connect components of the design in a professional manor. Assistance will also be required to 3D print the project case which will house all the components.

RISKS

Removal of Team Member

If a team member is removed from the project their tasks and responsibilities will be split between the two remaining team members. The likelihood of this happening is very low. However, if this does occur there will be a significant increase in overall workload for the remaining team members. Certain features may be removed from the device to simplify the design and lessen the overall workload.

Falling Behind Schedule

This project risk has a higher likelihood of occurring as we only have 3 team members. In order to prevent falling behind schedule, we will discuss our progress during weekly meetings. If a particular task is taking longer than expected, we may assign an additional team member to the task or decrease the number of tasks assigned to a team member. By decreasing the number of tasks assigned to a particular team member, they can focus on the more time-consuming task. Due to participating in the MOSIS program this is less of a risk for us in the Spring as we will have a majority of our design done this Fall.

MOSIS Chip Problems and Delay

The likelihood that the MOSIS chip will have a delayed arrival is low. Even though last years MOSIS chips didn't arrive until May, this was the first time a MOSIS chips had been delayed for over ten years. If the MOSIS chip is delayed or damaged, the contingency plan will be to use an FPGA (Field-Programmable Gate Array).

Damaged Components

The chance we receive damaged components on arrival will be relatively low. However, to account for this possibility, we will be ordering and testing our parts during the Fall semester. If there are any damaged components, we will have plenty of time to return or reorder any parts in the Spring semester.

Assembly Issues

Issues may arise when assembling all of the components of the project. To minimize the possibility for errors, the entire group has agreed upon each of the inputs and outputs of each device. In addition, we will be consulting Jared Rees, the Engineering Technician at UP, to ensure all of the parts will be compatible prior to ordering.

CONSTRAINTS

Technical

The only technical requirements for the user to play our prototype would be to know the basic rules of Battleship. Many of the rules will be incorporated into the design like the number of ships needed to be placed and valid ship placement. However, we are not including a list of rules on how to play the game. If this product was commercially produced, a list of rules and instructions for beginner players would be included.

Economical

The economical constraints on our project are set upon us by University of Portland funding. Each project is allowed no more than $400 without a budget extension. The likelihood we go over budget is relatively low because we only need two LED matrixes and a handful of electrical components.

Environmental

We have set no environmental constraints on the project. Since the final product will be powered from an outlet and we have no control over how the parts are produced, we have little control over the environmental effects of our device. What we can control is our device's power efficiency. Therefore, we will design our power supply in a way which minimizes the power needed to reliable drive the device.

Ethical and Legal

Since this product is a remake of the traditional board game Battleship, we would not mass produce the final product without consulting a legal firm. There are many versions of electronic Battleship, but we would need to ensure our design is unique enough to avoid copyright infringement.

Health and Safety

The main concern for health and safety while using our device will be electrical shocks. There will be a relatively low chance of this occurring while assembling the prototype because our device will operate at low voltage and current levels. Furthermore, our device casing will seal any electrical components away from the user eliminating any chance of shocking the user.

Manufacturability

Our main constraint on manufacturability will be regarding the game logic controller. MOSIS, a company from Marina del Rey, California, will be designing a custom processing chip for our project. The deadline for submitting our initial plans on how our chip should be designed is October 31st, and the final deadline is November 16th. This will allow MOSIS enough time to manufacture the chip prior to assembling our prototype during the Spring semester.

CONCLUSION

This project consists of designing, testing, and building a functional and modern prototype of the well-known game Battleship. Throughout the design process our team will be given the opportunity to utilize the knowledge and skills we have gained throughout our time at the University of Portland. A majority of the game functionality will be designed and fabricated into a chip through the MOSIS program which will develop our digital design and Verilog skills. We will also be using numerous Raspberry Pis to interface with the LED matrixes that will act at the player's screens. While we anticipate this device will be used primarily for Entertainment purposes, this device can also be used as an education aid for digital design as well as cognitive development and teaching strategy skills for children. While our finished project, BattleChip, will closely resemble the current Battleship game on the market, ours will include many updated features that resembles the current era of technology.

Glossary

FSM - Finite State Machine

Game Logic Controller - Hardware Logic Controller Fabricated by the MOSIS Educational Program.

Display System - Two Raspberry Pis connected to the game logic controller and LED matrices.

RGB - LEDs that can display Red, Green, and Blue allowing for all colors to be shown.

MOSIS Educational Program – A program by the MOSIS Service allowing for low cost chip fabrication for universities.

PCB - Printed Circuit Board allowing for clean connections between components.

IC - Integrated Circuit

FPGA - A Field Programmable Gate Array can be used to simulate hardware designs.

Raspberry Pi - An inexpensive single board computer which can be programmed and has I/O pins allowing for easy interaction with other electronics.

Bibliography

"Battleship Game Rules." *Board Game Capital*, 2018, www.boardgamecapital.com/battleship-rules.htm.

"LM555 Timer." *Texas Instruments*. 2015, www.ti.com/lit/ds/symlink/lm555.pdf.

"MOSIS Educational Program." *The MOSIS Service*, 2018, www.mosis.com/pages/products/mep/mep-instructional.

"The Benefits of Board Games." *Scholastic | Parents*, 2018, www.scholastic.com/parents/kids-activities-and-printables/activities-for-kids/arts-and-craft-ideas/benefits-board-games.html.

Appendix A

Below are the rules of Battleship which we followed when designing our project. The source for these rules can be found in the Bibliography.

Game Preparation:

The easiest way to set up the game of Battleship is to sit facing your opponent with each target/ocean field facing away from each other. You should not be able to see your opponent's hidden fleet. The Battleship rules state that each player should hide all five ships secretly somewhere on their ocean. Each ship has two anchoring pegs that must be pushed through the holes on the ocean grid. All holes on the ships must align over the holes of the ocean board. It is against the rules to place any ship diagonally on your ocean. Once all ships have been placed and each player announces that they are ready, the game of Battleship begins. Changing the position of your ships during the game is also against the rules.

Game Play:

The basic Battleship rules and instructions for playing the game are each player calls out one shot (or coordinate) each turn in attempt to hit one of their opponent's ships. To "hit" one of your opponent's ships, you must call out a letter and a number of where you think one of their ships is located. The instructions state that once a shot is called, the opponent must immediately call out "hit" or "miss." If one of your ships gets hit, place a red peg over the hole location on your ships that was called out. If calling a shot (or trying to hit your opponent's ships), mark a red peg (if a hit was made) or a white peg (a miss) on your target grid located on the lid or the vertical divider between you and your opponent. This will help you keep track of your hits and misses in your hunt to find their ships.

Once all holes on a ship have been filled with red pegs, your ship has sunk and must be removed from the ocean. You then announce which ship has sunk. The Battleship rules on successfully sinking a ship are as follows: Carrier – 5 hits, Battleship – 4 hits, Cruiser – 3 hits, Submarine – 3 hits, Destroyer – 2 hits. It is considered cheating and against the Battleship rules to be dishonest on the location of your ships.

APPENDIX B

The Texas Instruments 555 Timer integrated circuit will be a crucial part of the project. This will create a stable clock for the sequential elements of the design to use. Without it, none of the FSMs could run. Below is the schematic of the circuit provided on the IC.

Schematic Diagram